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THE EFFECT OF BINOCULAR RIVALRY ON THE PERFORMANCE OF A SIMPLE TARGET DETECTION/RECOGNITION TASK (U)

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This technical report has been reviewed and is approved for publication.

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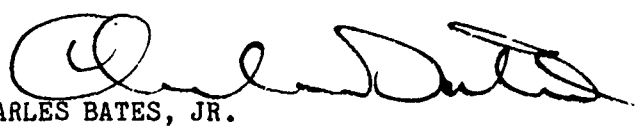

CHARLES BATES, JR.
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A study was conducted to investigate the effect of binocular rivalry on a simple target detection/recognition task. Six observers were required to detect and identify a target numeral (6, 7 or 8) that was embedded in a matrix of letters (Bs, Gs or Zs). Binocular rivalry was induced by using monocular fields differing in color (red vs. green) and type of letters (Bs vs. Gs, Gs vs. Zs, etc.). The different monocular fields were presented to the observer using a Master Orthorater vision tester and specially constructed slides. Results from this study indicated that target detection/recognition times increased by a factor of 5 under binocular rivalry conditions. Implications of this finding to an operational situation are discussed. Keywords: visual perception; image registration; vision

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PREFACE

This report was prepared by the Crew Systems Effectiveness Branch, Human Engineering Division, Armstrong Aerospace Medical Research Laboratory (AAMRL), Wright-Patterson Air Force Base, Ohio under Project 7184, Task 718411, Work Unit 7184-11-46, "Advanced Visually Coupled Systems and Display Concepts." Principal investigator for this research was Mr William N. Kama.

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Session 1

INTRODUCTION

In using a visually coupled system (VCS), the operator views two monocular fields that are superimposed. Additionally, these fields may vary in brightness due to the occlusion/non-occlusion of one eye or through the use of a "see through" display. This condition (viewing two monocular fields of differing brightness) can lead to the phenomenon of binocular or retinal rivalry, a condition in which, if the eyes gaze upon two different visual fields that cannot be given a unitary interpretation, alternation between the two fields occurs.

In surveying the literature on binocular rivalry, Hughes, Chason & Schwank (1973) indicated that most of the research performed in this area had been directed toward determining those factors which either affect the frequency or influence the temporal dominance of one field over the other. Physical variables that were investigated included contrast, brightness, contour, continuity, illumination, interest, movement, and color of the competing fields. Findings from these studies indicated that the dominant field (1) had the greater figure-ground contrast, (2) was brighter, (3) had more contours, (4) had continuous rather than broken contours, (5) was more interesting, and (6) was dynamic rather than stationary. Additionally, as illumination of both fields was increased, the alternation rate also increased.

Although the study of these variables and their influence upon the occurrence or non-occurrence of binocular rivalry is of interest, the

question of interest here is not that binocular rivalry occurs with the use of a VCS, but rather "given the occurrence of binocular rivalry, what is its effect upon the operator's information processing capability?" The purpose of this study was to obtain an answer to this question.

Section 2

METHODOLOGY

Apparatus

The apparatus used in the conduct of this study was the Armed Forces Vision Tester or Master Orthorater (see Figure 1). This apparatus is used to measure the visual abilities of human observers and was selected for use in this study because it afforded both monocular and/or binocular presentation of visual stimulus material.

Special slides were designed and fabricated for use in this study. These slides consisted of two monocular fields composed of red and green letters (Bs, Gs, or Zs) arranged in a 5 x 6 matrix. A target numeral was embedded in one of these fields. Numerals used were "6", "7", and "8". The 6 was embedded in a matrix of Gs; the 7 in a matrix of Zs; and the 8 in a matrix of Bs.

A total of six such slides were generated (see Figure 2). In each slide, the matrix of letters in the left visual field was red while the letters in the right visual field were green. In three of the slides, the target numerals were red and located in the left visual field while in the other three they were green and located in the right visual field. Binocular rivalry was induced by the difference in color of the monocular visual fields and also by the letters used in the visual fields.

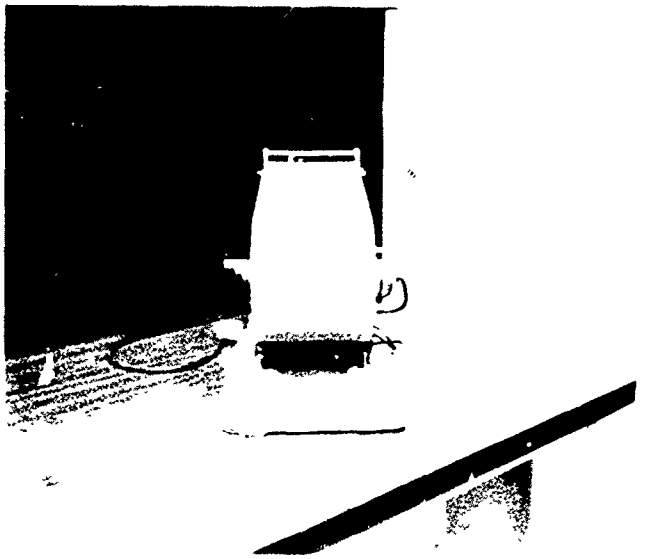

Figure 1. The Armed Forces Vision Tester (Master Orthorater) used in this study.

Z	Z	7	Z	Z	Z		B	B	B	B	B	B
Z	Z	Z	Z	Z	Z		B	B	B	B	B	B
Z	Z	Z	Z	Z	Z		B	B	B	B	B	B
Z	Z	Z	Z	Z	Z		B	B	B	B	B	B
Z	Z	Z	Z	Z	Z		B	B	B	B	B	B

Slide 1 - Red Zs and numeral 7 (left) and green Bs (right)

G	G	G	G	G	G		Z	Z	Z	Z	Z	Z
G	G	G	G	G	G		Z	Z	Z	Z	Z	Z
G	G	G	6	G	G		Z	Z	Z	Z	Z	Z
G	G	G	G	G	G		Z	Z	Z	Z	Z	Z
G	G	G	G	G	G		Z	Z	Z	Z	Z	Z

Slide 2 - Red Gs and numeral 6 (left) and green Zs (right)

B	B	B	B	B	B		G	G	G	G	G	G
B	B	B	B	B	B		G	G	G	G	G	G
B	B	B	B	B	B		G	G	G	G	G	G
B	8	B	B	B	B		G	G	G	G	G	G
B	B	B	B	B	B		G	G	G	G	G	G

Slide 3 - Red Bs and numeral 8 (left) and green Gs (right)

B	B	B	B	B	B		Z	Z	Z	Z	Z	Z
B	B	B	B	B	B		Z	Z	Z	Z	Z	Z
B	B	B	B	B	B		Z	Z	Z	Z	Z	Z
B	B	B	B	B	B		Z	Z	Z	Z	7	Z
B	B	B	B	B	B		Z	Z	Z	Z	Z	Z

Slide 4 - Red Bs (left) and green Zs and numeral 7 (right)

Z	Z	Z	Z	Z	Z		G	G	G	G	G	G
Z	Z	Z	Z	Z	Z		G	G	6	G	G	G
Z	Z	Z	Z	Z	Z		G	G	G	G	G	G
Z	Z	Z	Z	Z	Z		G	G	G	G	G	G
Z	Z	Z	Z	Z	Z		G	G	G	G	G	G

Slide 5 - Red Zs (left) and green Gs and numeral 6 (right)

G	G	G	G	G	G		B	B	B	B	B	B
G	G	G	G	G	G		B	B	B	8	B	B
G	G	G	G	G	G		B	B	B	B	B	B
G	G	G	G	G	G		B	B	B	B	B	B
G	G	G	G	G	G		B	B	B	B	B	B

Slide 6 - Red Gs (left) and green Bs and numeral 8 (right)

Figure 2 - Drawings of six stimulus slides used in the study.

Treatment Conditions

Subjects were tested under two treatment conditions. Under Condition I, the subjects were shown either the left or right visual field, i.e., monocular viewing. Under Condition II, they viewed both the left and right monocular fields simultaneously, i.e., binocular viewing. This latter viewing condition resulted in the inducement of binocular rivalry. Condition I served as a baseline or comparison condition.

Subjects

A total of six male subjects, all with normal or corrected 20/20 vision and no color deficiencies, were used. All subjects were tested under both treatment conditions. Half of the subjects received Condition I first followed by Condition II, while the other half received Condition II first followed by Condition I. The order of presentation for the six slides was randomized and counterbalanced so that each slide occurred first, second, etc. an equal number of times. This was done to combat possible practice or learning effects. All subjects were naive with respect to the task employed.

Task

The task used was a simple target detection/recognition task. Subjects were required to detect a target (which was embedded in a matrix of letters), correctly identify it, and give its location in the matrix (row and column) within a two-minute time period. Thus a typical response would be "numeral 6, row 3, column 4."

Procedure

The following procedure was adhered to during the testing of each subject: Upon his arrival, each subject was given a visual acuity and color deficiency test to ensure that he had normal acuity (20/20) and color vision. He was then instructed as to the purpose of the study and the task to be performed by him. He was also instructed as to the manner in which he was to respond, i.e., identify the target and give its location by row and column. After ascertaining whether there were any questions, each subject was given 12 2-minute trials, 6 under Condition I and 6 under Condition II. During a given trial, the subject placed his eyes in front of the eyepiece of the orthorater. When he was ready, the experimenter simultaneously turned on the light for the orthorater and started a timing device. When the subject verbally indicated that he had detected the target, the experimenter stopped the timing device, turned off the orthorater light, and changed the stimulus slide. After recording the responses for that trial, the next trial was administered. If the subject did not detect the target within the required two-minute period, the trial was terminated and the subject was given a miss for that trial. Performance was evaluated in terms of detection time and correct identification.

Section 3

RESULTS

The data obtained in this study (shown below) were analyzed by means of a small sample t-test for matched samples (Lindquist, 1953). Analysis of the obtained data resulted in the following findings:

	Condition I		Condition II	
	Detection(sec)	%Correct	Detection(sec)	%Correct
Subject				
1	2.9	100	11.8	100
2	3.4	100	22.8	100
3	2.7	100	16.8	83
4	4.3	100	11.2	50
5	4.4	100	31.5	50
6	5.5	100	26.7	100
Mean	3.9	100	20.1	80.5

A significant difference ($p < .01$) between the monocular and binocular viewing condition was obtained for the detection time measure. A t-ratio of 5.17 was obtained. The obtained means were 3.9 seconds for monocular viewing and 20.1 seconds for binocular viewing (the rivalry condition). These obtained means indicate that under binocular rivalry, it took five times longer to detect the target as compared with the non-rivalry condition. Additionally, 5 misses and two false alarms (i.e., detection occurred but the wrong target was identified) occurred under the rivalry condition while none occurred under the non-rivalry condition.

In addition to detection time, percent correct identification was also used to evaluate subject performance. This measure was obtained by taking the ratio of correct identification to the total number of trials and multiplying by 100. For Condition I, a mean percent correct identification score of 100 was obtained while for Condition II a score of 80.5 was obtained. This reduction in performance was due to the occurrence of 5 misses and 2 false alarms under the rivalry condition. The t-test performed on this measure yielded a t-ratio of 2.34. This value was found to be of no significance.

Section 4

DISCUSSION

The results of this study indicate that even under conditions of binocular rivalry, an operator is still able to acquire and process information. However, the time required for this acquisition and processing is significantly increased by a factor of 5 over a non-rivalry situation. Under the non-rivalry condition, it took 3.9 seconds to detect and identify a target; while under the rivalry condition, it took 20.1 seconds to perform the same task.

In addition to the increased time required to detect a target, there is also a reduction in accuracy performance. Performance for the non-rivalry condition was 100% while that for the rivalry condition was 80.5%. This reduction was due to the fact that under the rivalry condition some of the targets (5) were not detected and in two instances they were detected but incorrectly identified.

In terms of the information processing paradigm, the increase in acquisition (detection) time can be attributed to the fact that binocular rivalry has its effect on Stage I. In the basic information processing paradigm (see Figure 3), Stage I represents the encoding of any external stimulus that occurs. During this stage, several subprocesses occur. For instance, as a stimulus arises, information from that stimulus is encoded and held momentarily in short term memory, the icon. A SCAN mechanism samples the icon and transmits such sampled data to a recognition buffer memory where a preliminary analysis establishes the particular ensemble in long term memory (store) that is to be used in Stage II.

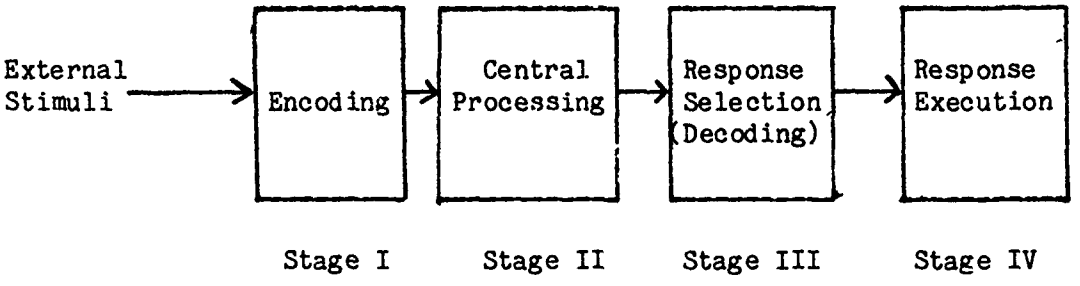

Figure 3. A basic model of human information processing (After Smith, 1968).

The particular effect of rivalry on the information processing chain is to inhibit the encoding of the stimulus by preventing the information from the stimulus to be readily acquired. In fact, as the data indicated, it took almost 5 times longer to get the necessary information from the stimulus before it could be encoded so that the information processing chain could proceed. In some cases, the information was never obtained and thus the stimulus was neither detected nor identified.

The fact that binocular rivalry significantly increased the time required for acquiring and processing information (and in some cases prevented it) has serious implications for the proper design and operational use of a visually coupled system. Take for example a typical mission profile against a known pre-briefed tactical target (see Figure 4). After penetrating at low level, the aircraft "pops up" to unmask the target. The pilot then has approximately 2-4 seconds to search for (locate) the target, 4-6 seconds to detect it, and 2 seconds to recognize it and then deliver his ordnance. From the time the pilot initiates his search and fires his weapon, a total of 12 seconds (maximum) has

transpired. The data obtained indicates that it takes 20 seconds just to complete the search and detection portions of this sequence, a time far in excess of what is required for weapon system survivability.

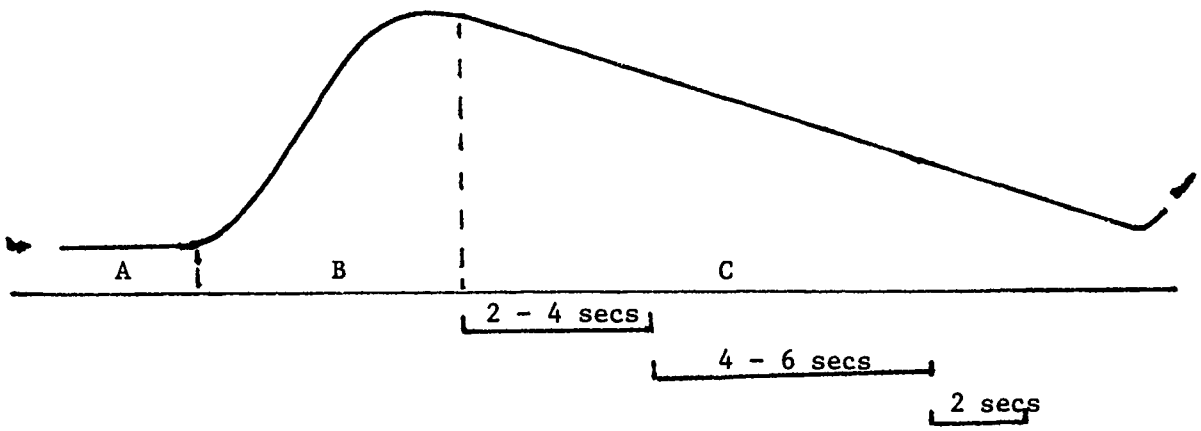

Figure 4. Typical mission profile against known, prebriefed target showing A (low level penetration), B (pop up) and C(search, detection and weapon delivery).

When one considers that this 20 second search and detection time was obtained under benign, laboratory conditions, the severity of the problem is amplified tremendously. The visual fields will be changing dynamically (different brightness, contrast, etc.) and environmental factors as well as mechanical factors (e.g., vibration) will need to be considered. When these factors are taken in concert with the high threat environment that the aircraft is in, search and detection time should increase even more.

It is suggested that a follow-on experiment should be conducted to investigate the effects of binocular rivalry upon target detection performance using dynamically changing visual fields.

Section 5

SUMMARY

A study was conducted to determine the effect of binocular rivalry upon target acquisition performance. Six observers were required to detect and identify a target (the number 6, 7 or 8) embedded in a matrix of letters (Bs, Gs, or Zs). The results obtained indicated that binocular rivalry increased detection time by a factor of 5 (3.9 to 20.1 seconds). Although correct identification performance decreased from 100% to 80.5% under the rivalry condition, this increase was not statistically significant.

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